Russian system of countermeasures on ISS

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Main adverse effects of hypogravity on human body systems

- Skeletal bones demineralization;
- Deconditioning, atrophy and structural changes in the muscle apparatus;
- Cardiovascular deconditioning;
- Degradation of general physical performance;
- Loss of orthostatic tolerance;
- Disorders in coordination of movements (posture, locomotion, target acquisition);
- Reduction of g-load tolerance.

THE RUSSIAN SYSTEM OF COUNTERMEASURES

- **PHYSICAL METHODS AIMED TO DIMINISH FLUID REDISTRIBUTION IN WEIGHTLESSNESS (LBNP, OCCLUSIVE CUFFS) AND DURING READAPTATION TO 1G (ANTI-G-SUIT);**

- **PHYSICAL EXERCISES AIMED TO LOAD THE MUSCUL0SKELETAL AND CARDIOVASCULAR SYSTEMS, TO STIMULATE THE PROPRIOCEPTIVE SYSTEMS AND TO MAINTAIN FUNCTIONALITY OF THE POSTURE AND LOCOMOTION CONTROL SYSTEMS;**

- **MEASURES FOR FLUID RETENTION - WATER-SALT SUPPLEMENTS;**

- **PHARMACOLOGICAL ABATEMENT OF NEGATIVE VESTIBULAR, METABOLIC AND OTHER REACTIONS TO WEIGHTLESSNESS.**

Countermeasure currently available on the ISS

- Treadmill (TVIS)
- Bicycle ergometer (VB-3)
- Force training device (NS-1)
- Expanders (bungees)
- Electromyostimulator (Tonus-3)
- Electromyostimulator (Stimul-01 NCh)
- Axial loading suit PENGUIN
- Pneumatic vacuum suit CHIBIS (LBNP)
- Anti-G suit CENTAURUS
- Bracelet device (Bracelet-M)
- Water-salt supplements

SCHEME OF 4 DAYS TRAINING MICROCYCLE

Day	Goal	WWork load	Intensity of load	Energy expenditure
1	Maintenance of high velocity characteristics of muscle and of orthostatic tolerance	LLow	Submaximal and maximal	380-420 k/Cal (1591-1758 k/J)
2	Maintenance of strenght-velocity properties of skeletal muscles	MMiddle	Middle	450-500 k/Cal (1884-2093 k/J)
3	Maintenance of endurance properties and of movement coordination	HHigh	Small	550-600 k/Cal (2303-2512 k/J)
4	Active rest (exercises of cosmonaut's choice)	SSmall	ad libidum	about 150 k/Cal (628 kJ)

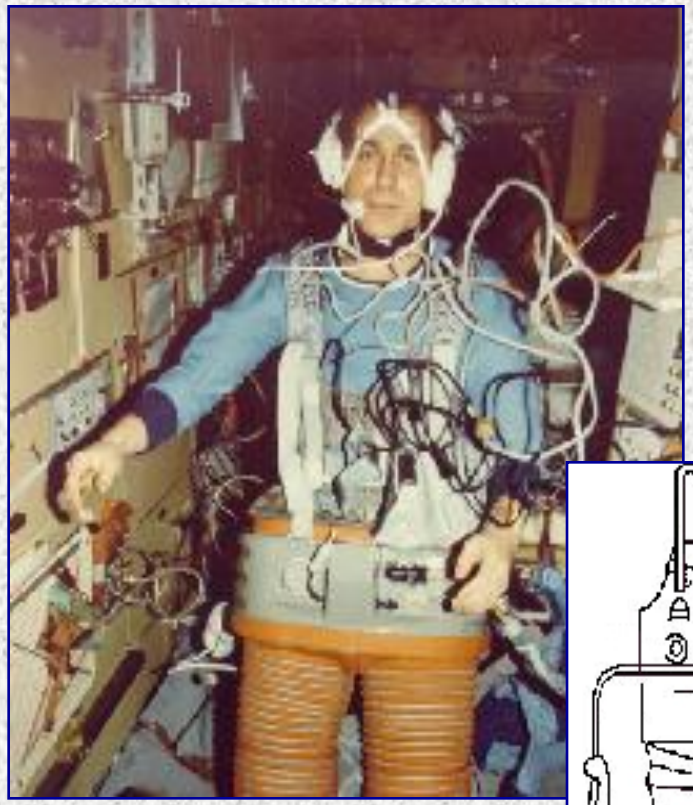
VELOERGOMETER VB-3

- **The onboard veloergometer provides a standard loading on the cardiovascular system. With an assortment of modes available - passive, active, and free, the veloergometer provides the capability of performing discrete loading with a power from 50 to 225 Wt given a pedaling frequency of 40-80 rpm.**

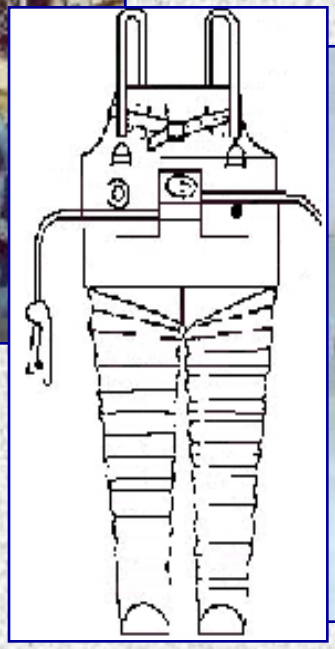
AXIAL LOADIND SUIT "PENGUIN"

- **The axial loading suit compensates in Space the load deficit in the musculosceletal system and also the deficit of weightbearing and proprioceptive afferentation.**
- **The tension of the elastic elements of the suit creates the «compressive» load along the body's longitudinal axis up to 40 kg.**

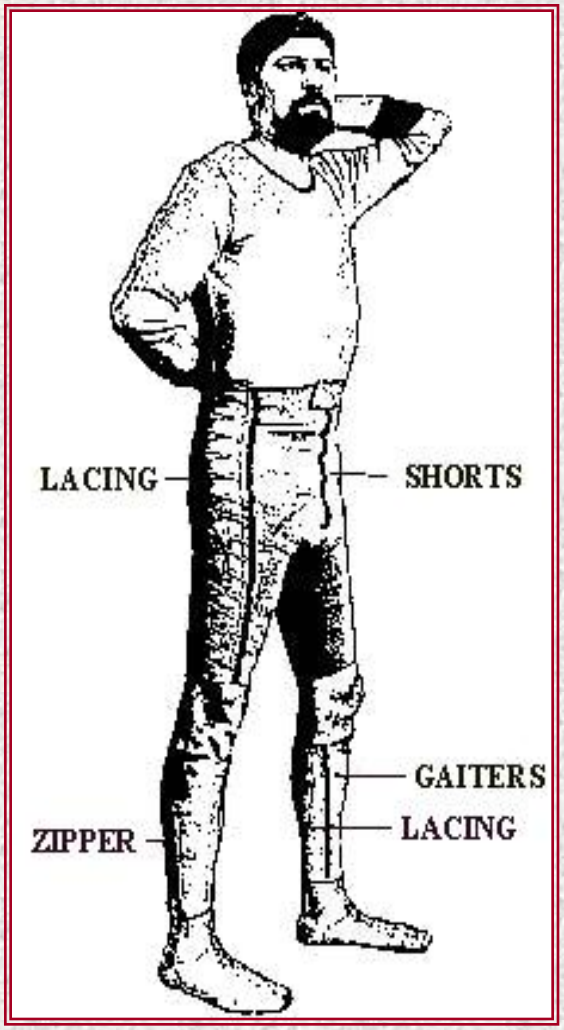
PREVENTIVE VACUUM SUIT "CHIBIS"



- **Low Body negative Pressure (LBNP) created by the vacuum suit CHIBIS is used to fight detraining effects of microgravity on mechanisms of orthostatic tolerance.**



ANTI-G SUIT "CENTAURUS"



The suit prevents pooling of body fluids in the legs and orthostatic collapse during and after landing and on the first days of readaptation to the Earth's gravity.

Schedule of the Russian program of countermeasures during long-duration ISS mission

1. **BEGINNING OF MISSION** (flight days 1-10): occlusive cuffs (p<50 mmHg, 20-30 minutes) and physical training at 50% of the prescribed loading

2. **PERIOD OF STABILIZATION:** two 1-hr. training sessions a day with the use of tread mill, bicycle ergometer, expanders, force loading device or electromyostimulation and “Penguin” facultatively

3. **PRE-EVA:** same training sessions with the emphasis on manual pedaling

4. **END OF MISSION** (-30 last days): two tread mill training sessions a day; 2-4 preliminary and two final (main) LBNP sessions; water-salt supplements (0,9% NaCl, 18-20 mL per kg of body mass, 3-4 times at the final 12-20 hours on mission)

5. **DEORBITING AND INITIAL DAYS OF READAPTATION:** ANTI-G SUIT “Centaur”

Performance of PhT by Russian cosmonauts in ISS SFs

N	SF days	PhT once a day	PhT twice a day	TVIS	Bicycle	IRED	Cuffs	"Penguin"	Tonus
1	142	1-100 days 100%	From 110th d. of SF – 100%	Walking from 11th d.; running – up to 7 miles from 47th day, with 40 kg loading	45-126 days Bi failed	Yes, intensively	no	Yes, without adequate loading	no
2	142	rare	mostly	The same, V-up to 9 km/h, loading up to 50 kg	-‖-	Yes, not intensively	no	Systematically with a good loading	no
3	167	First 50 days	The second half Нагрузка	Repairment up to 56 d., the last month 2 times, V-9-11 km/h, loading 46 kg	yes	yes+expanders in FGB	no	Yes, with a good loading	no
4	129	40%, 15% no PhT	45%	Up to 20 d. – no TVIS SLD, V – up to 12 km/h	yes	-‖-	no	50-60% of days	no
5	129	100%	-	Reduced usage	yes	Yes, intensively	no	no	no
6	196	100%		No TVIS SLD up to 137 d., loading – about 50 kg, low intensity and volumes	yes	No; expanders	First 3-4 days of SF	Yes, not adequate regimen 6-8 hrs/day	Yes, once a week

Performance of PhT by Russian cosmonauts in ISS SFs

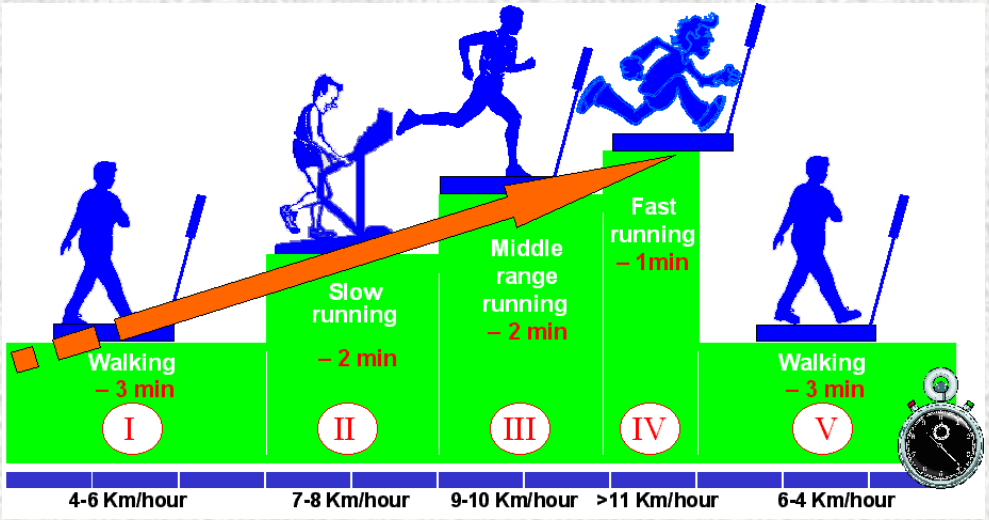
N	SF days	PhT once a day	PhT twice a day	TVIS	Bicycle	IRED	Cuffs	"Penguin"	Tonus
7	185	0% 1-30 d. No PhT	100%	Passive regimen -intensity up to 13 km, workload up to 10 km	yes	Yes+NS-1+middle size expander	yes	Yes, the whole working day	Yes, 10-12 times per flight
8	185	0%	100%	Low intensities and workloads. Last 30days – TVIS 2 times a day	yes	intensively	yes	Yes, regularly	Yes, 10-12 times per flight
9	195	0%	100%	Low intensity, 2-5 m/h, aerobic running, loading 40 kg from shoulders, at the end – TVIS 2 times a day	yes	No, NS-1 regularly	50% of SF	no	Occasionally
10	161	0%	100%	TVIS SLD – 30 days before landing, V – 10-11 km/h	yes	no	Yes, for a long time	no	yes
11	181	50%	50%	V – 2-4 m/h, workload 100%, walking/running - 1/3, loading 45kg, at the end 50 kg	yes	No, NS-1	First 2 weeks of SF	4-5 hrs/day 1 month before landing	1 month before landing
12	188	0%	100%	V – below 7 km/h, low loading	Yes, with MO-5 regimen	Highly intensive	First 2-3 weeks of SF	no	no

LBPN, water-salt loading, "Centaurus" were used before and during landing according to the standard protocol by all cosmonauts.

Monitoring of countermeasures' efficacy in SF

- **REGISTRATIONS OF PHYSICAL EXERCISES IN 4 DAYS MICROCYCLE**
- **TEST MO-3**
  Includes 11 minutes locomotor test and 2 test with bungee cords

Scheme of locomotor test



Parameters analyzed:

- Overall distance;
- Walking and running distances;
- Velocity on the steps;
- Heart rate on the steps and 3 minutes after stop;
- Lactate concentration before and after the test.

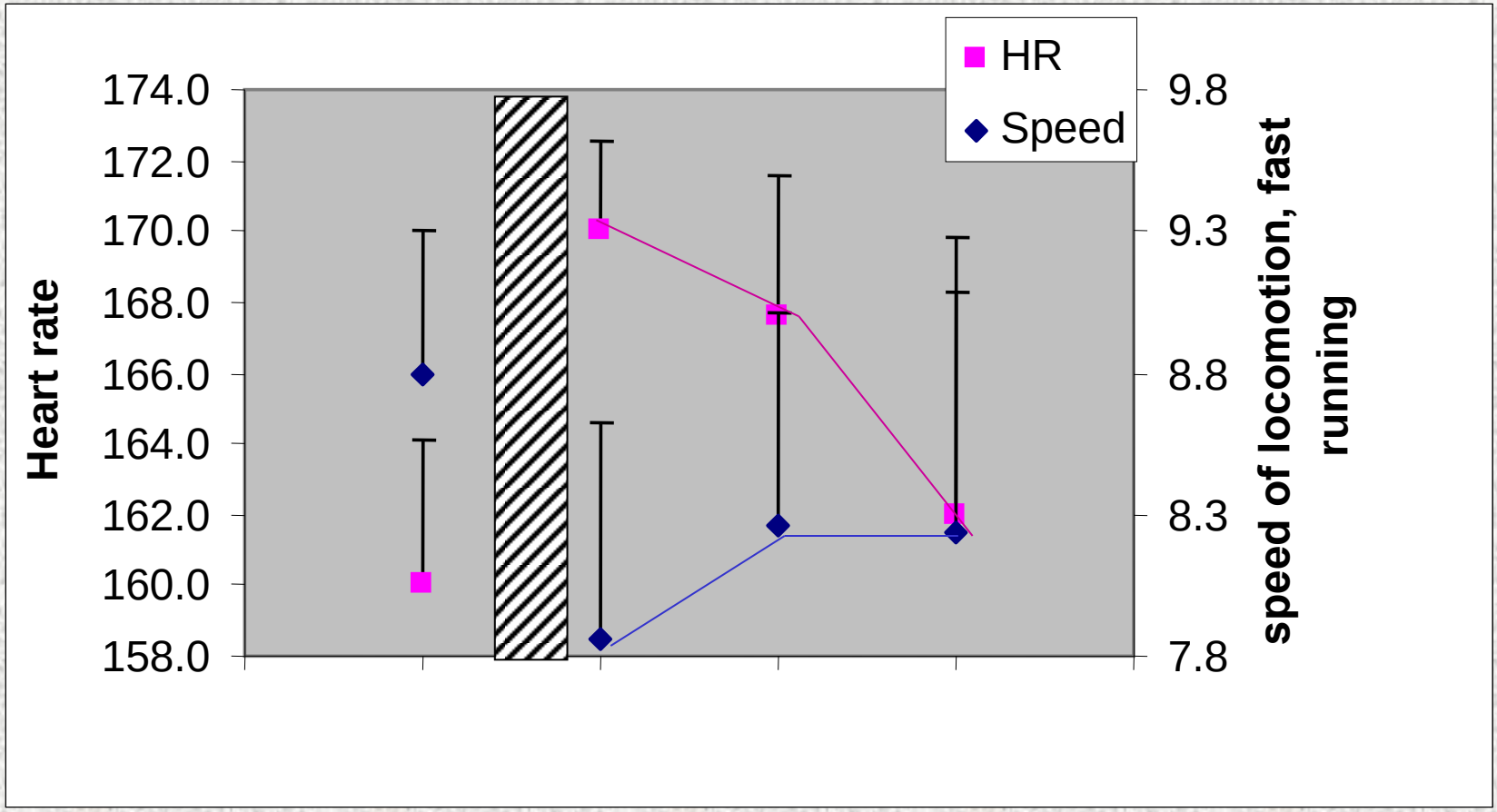
- **BEFORE EVA – HAND BICYCLING WITH THE INTENSITY 150 WTS**

- **TEST– MO-5**
  Data of clinical monitoring

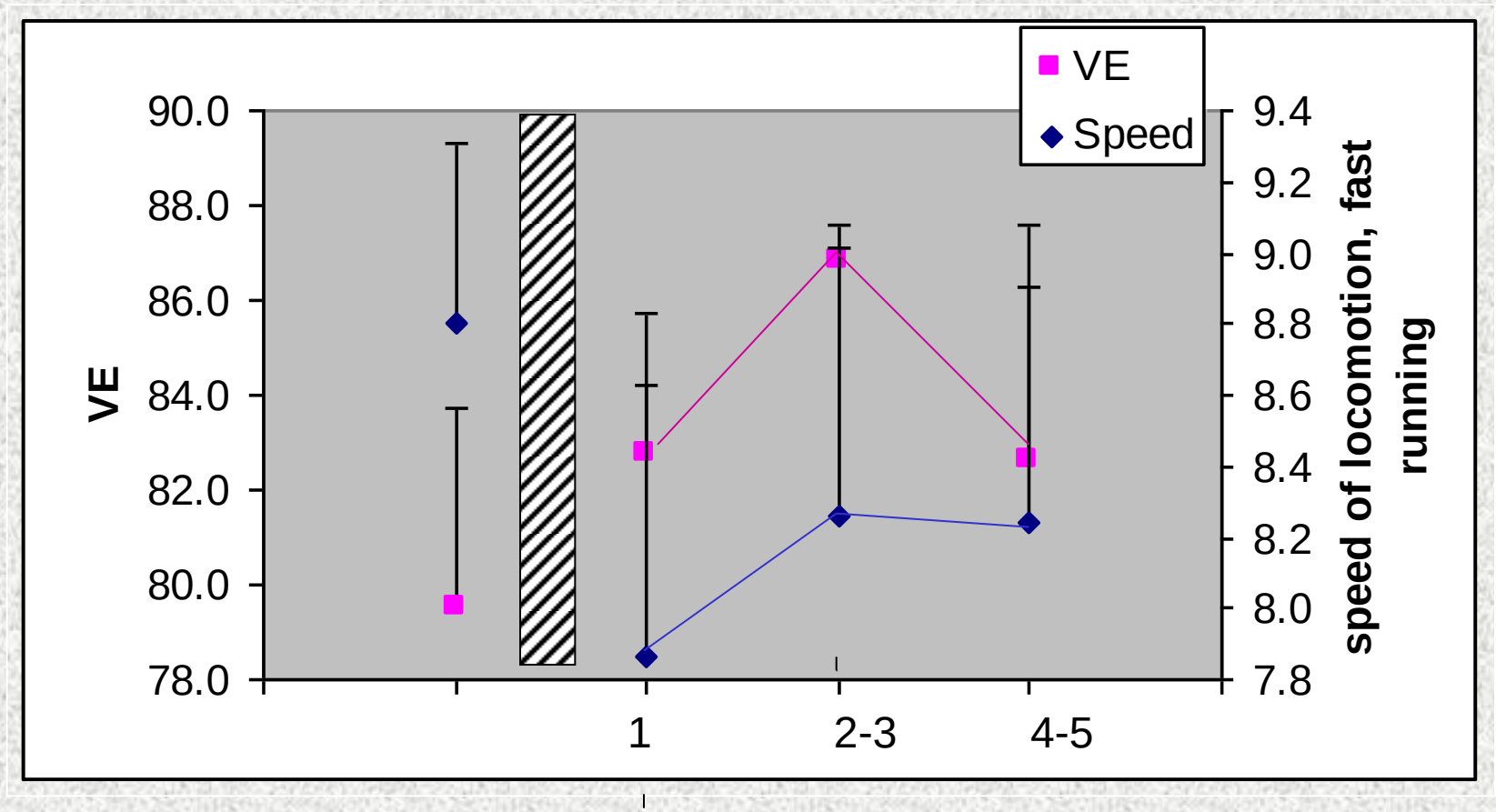
Characteristics analyzed:

- time of bicycling up to fatigue;
- maximal heart rate.

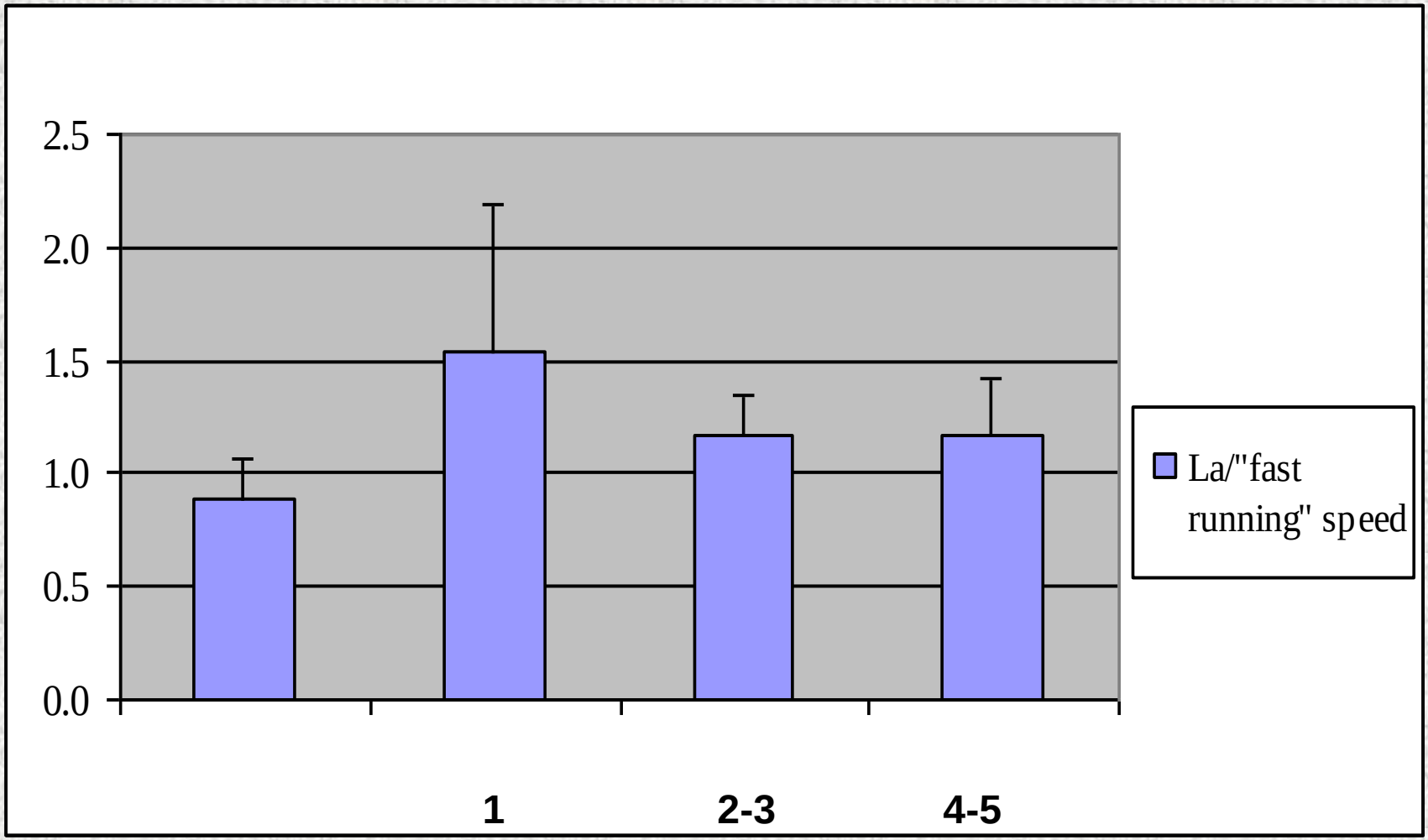
Alterations of characteristics of MO-3 during long term SFs in 5 members of ISS crews



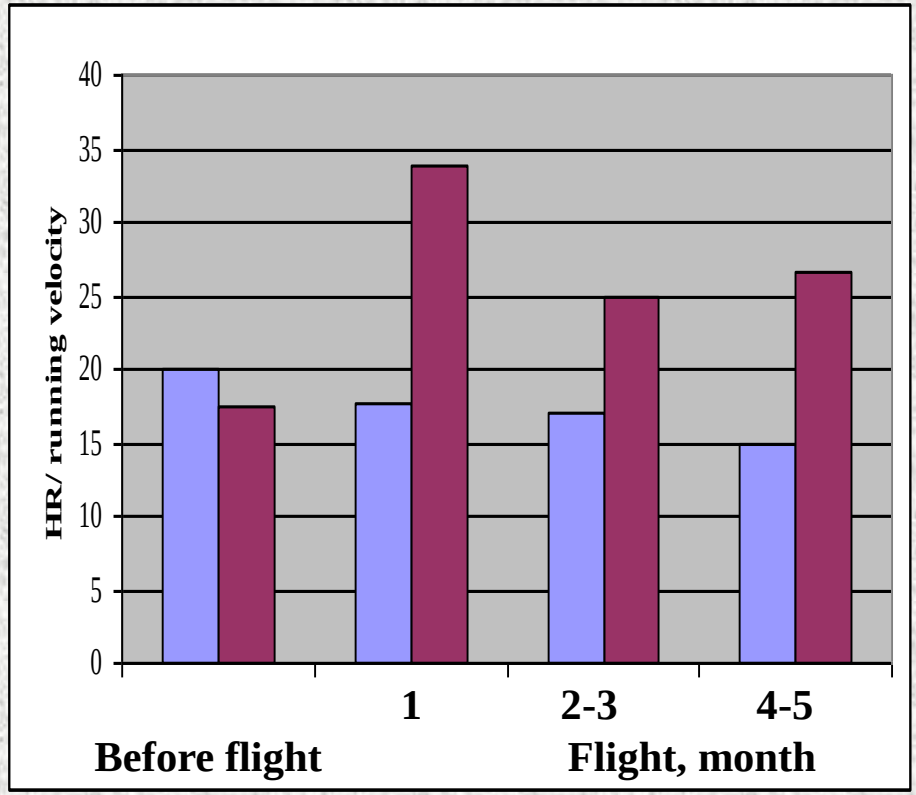
Changes of pulmonary ventilation during “fast running” step in long term SFs in 5 ISS crew members

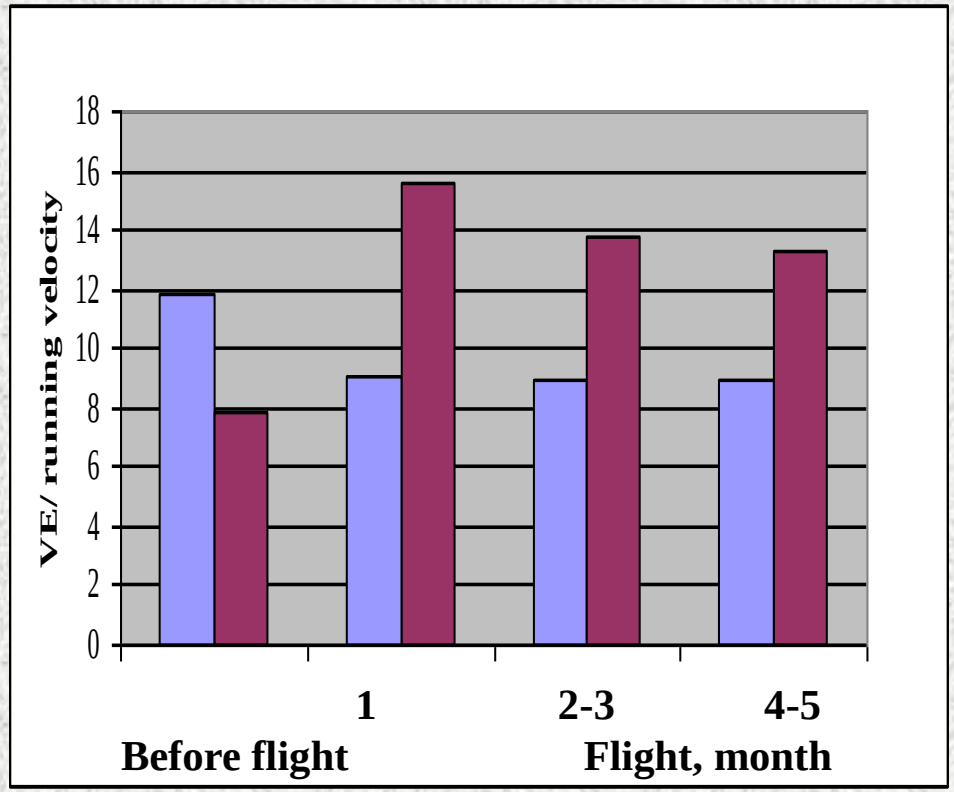


Changes of lactate blood concentration during MO-3 performance in STs on ISS; the mean data of 5 crew members



Changes of relations of main MO-3 characteristics during long term SF in ISS crew members





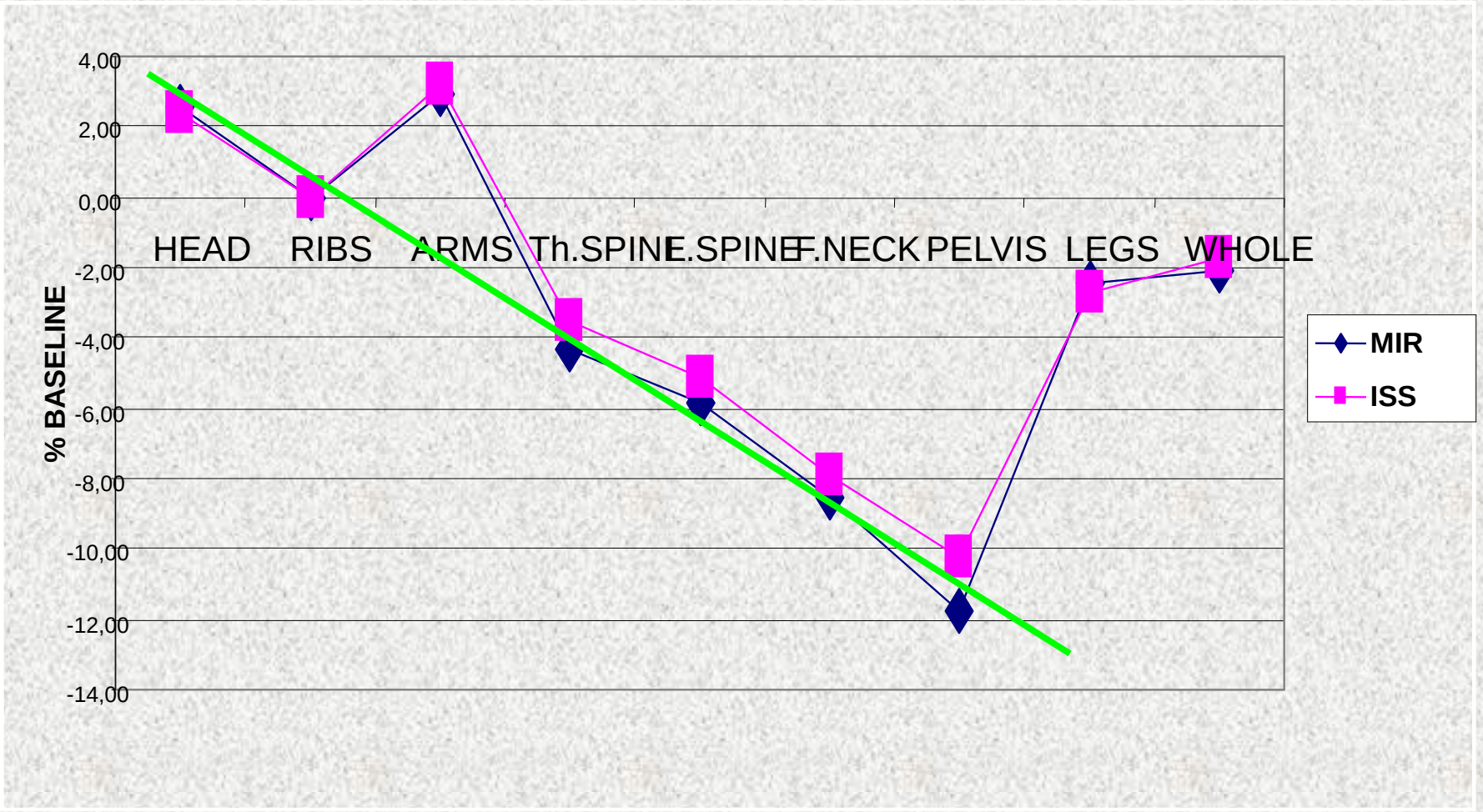
Data of cosmonaut A

Data of cosmonaut B

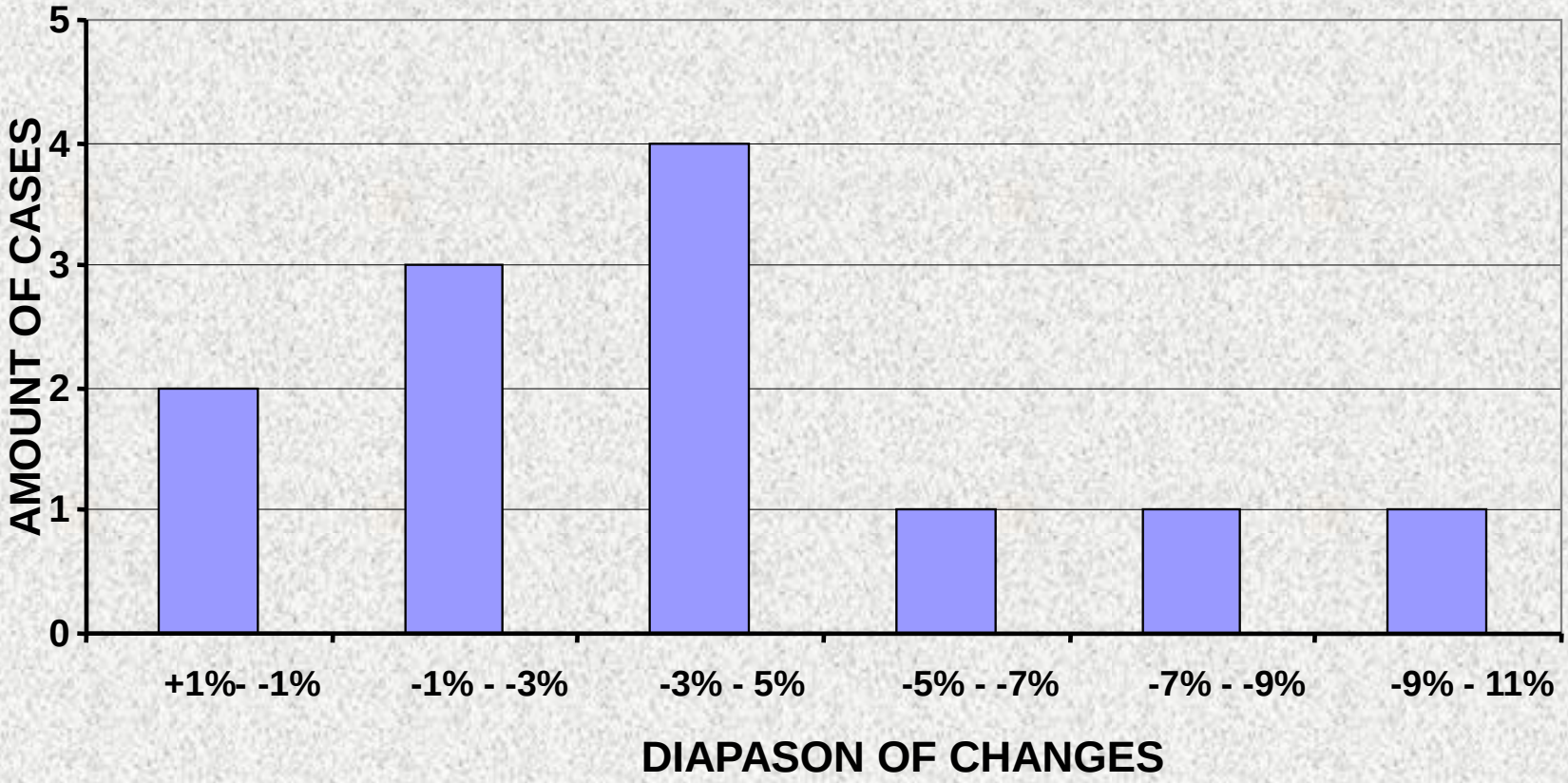
List of sensory-motor clinico-physiological evaluation studies (CSE) in Russian cosmonauts in ISS SFs

- **Bone characteristics**
  - **Densitometry**
- **Muscle properties**
  - **Isokinetic dynamometry of hip and leg muscles**
  - **Tendometry with tetanic contractions of leg extensors**
  - **Biopsy of m.Soleus**
- **Coordination**
  - **Stretch (Achill) reflex**
  - **Equilibrium (pushing test)**
  - **Control of accuracy of efforts gradation**
  - **Eye movements control**
  - **Locomotions**
- **Vestibular system characteristics**
  - **”Sensory adaptation” battery**

Bone mineral mass changes (%) after Mir and ISS 6 Mo flights (in the same cosmonauts gravitational trend for Mir data) (N=8)

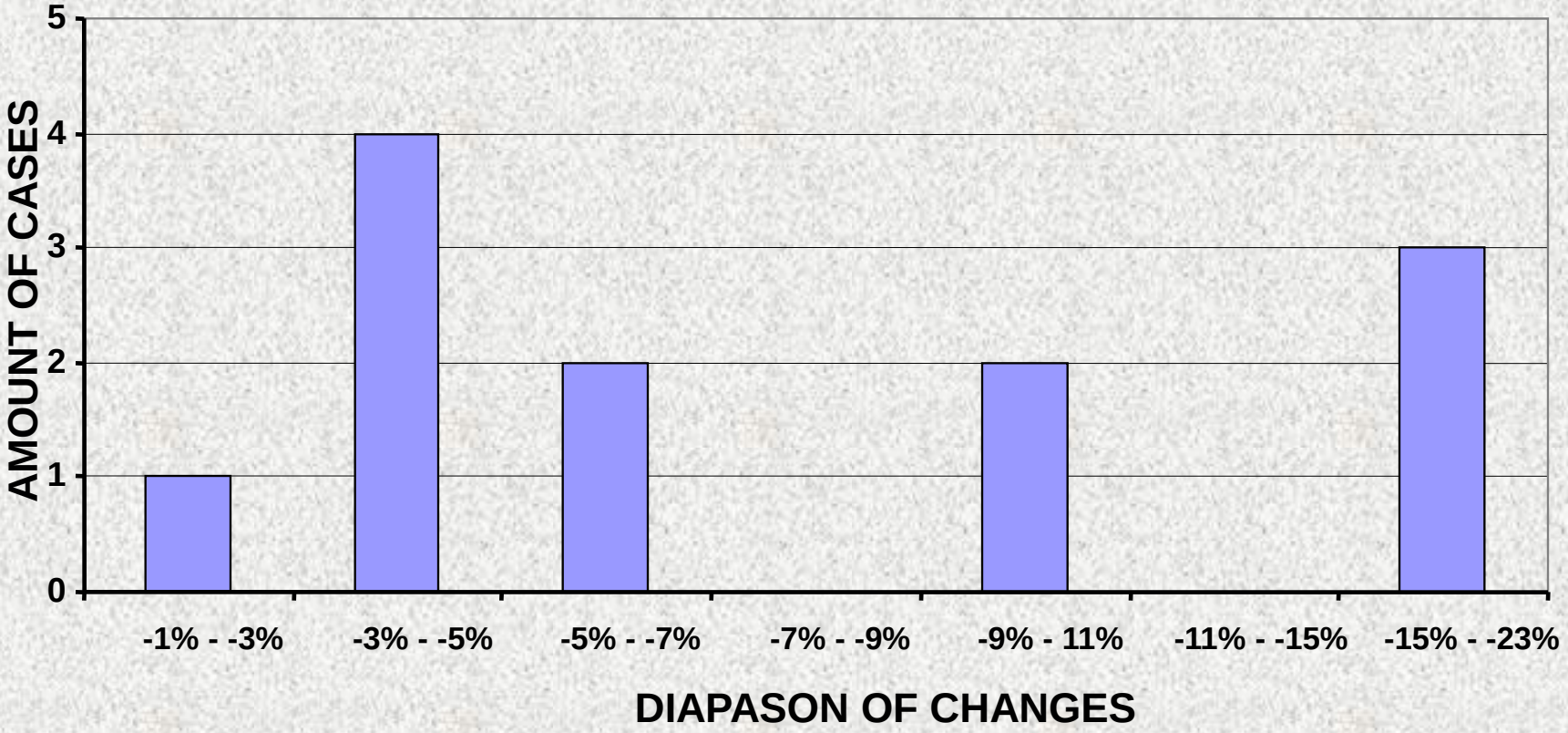


Histogram of lumbar spine bone mineral density changes in ISS space flights (n =12)

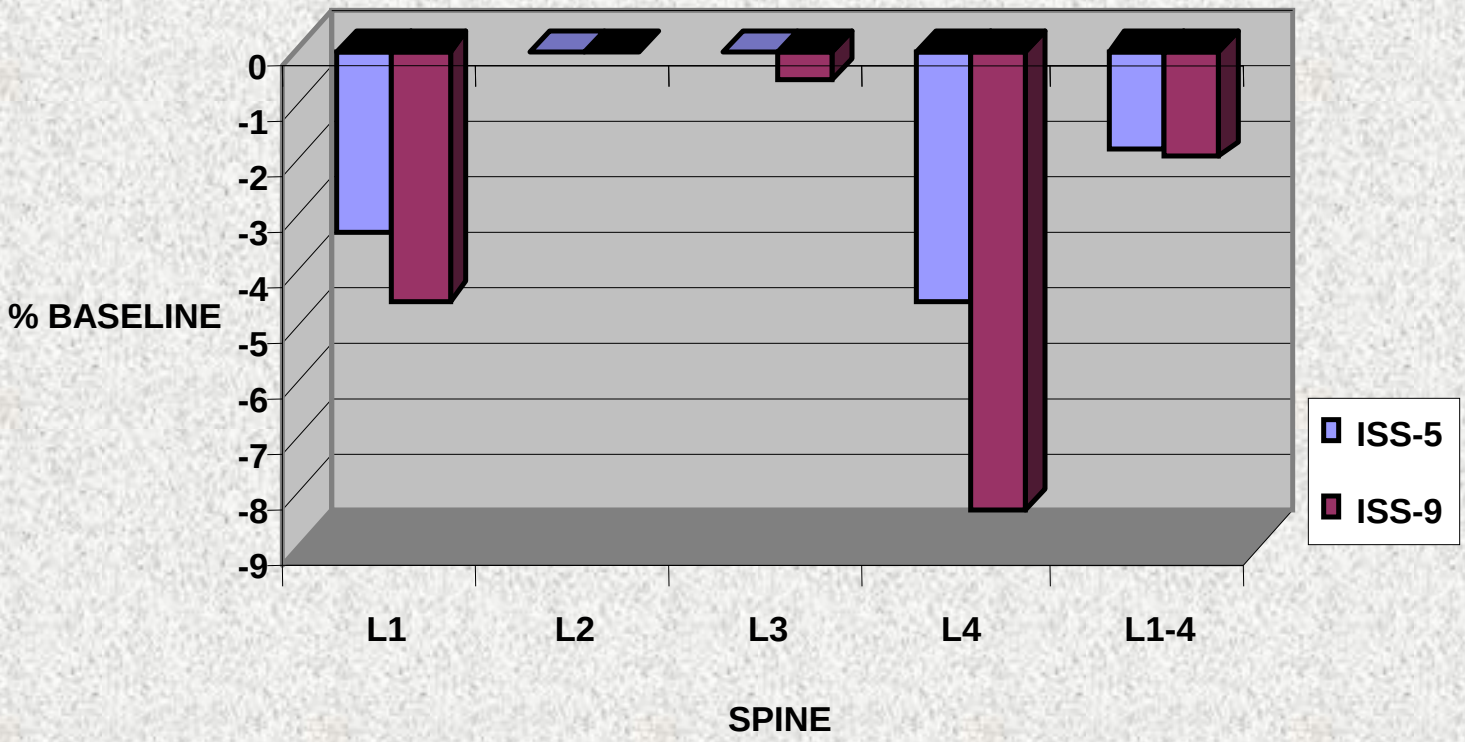


Histogram of femoral neck bone mineral density changes

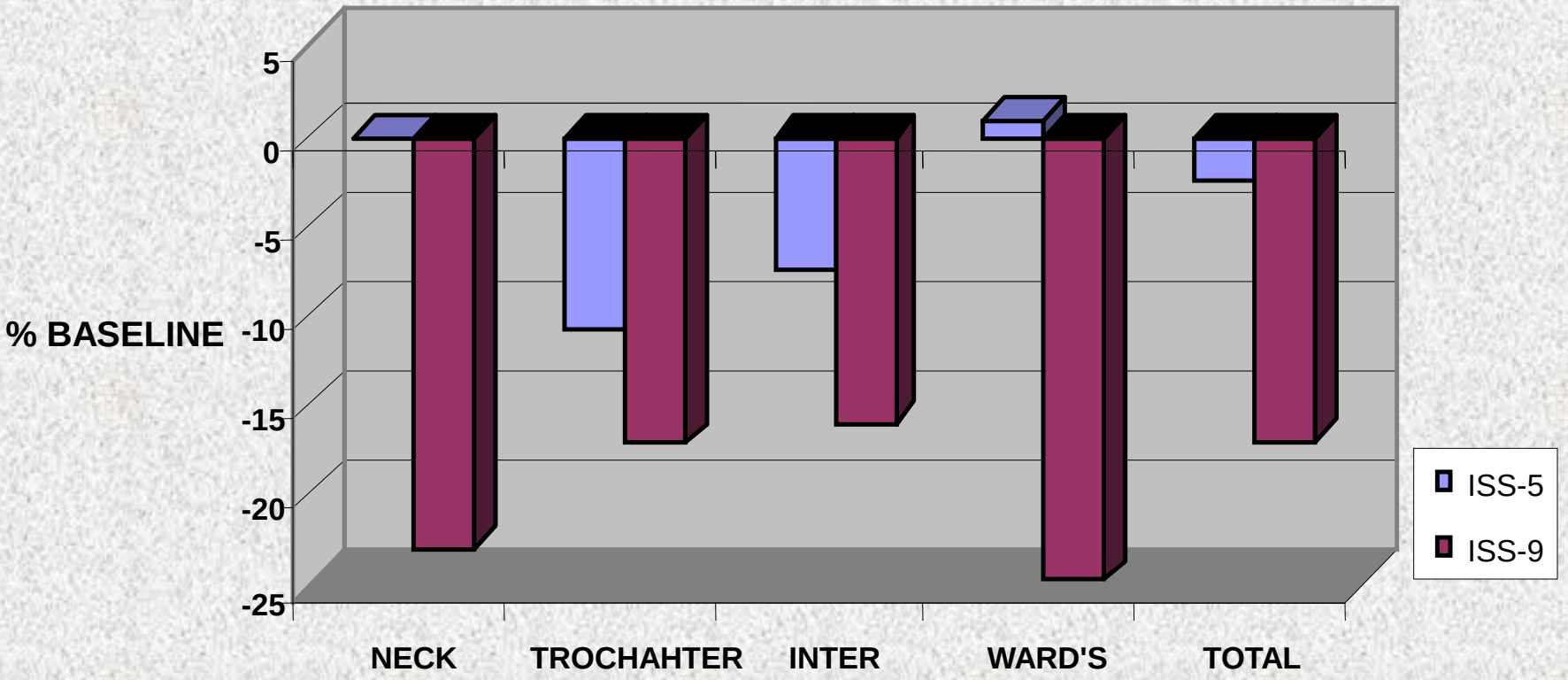
In ISS space flights (n=12)



Lumbar spine bone mineral changes in two cosmonauts after Space flights



Proximal femur bone mineral changes in two cosmonauts after space flights



Biopsy of m.soleus

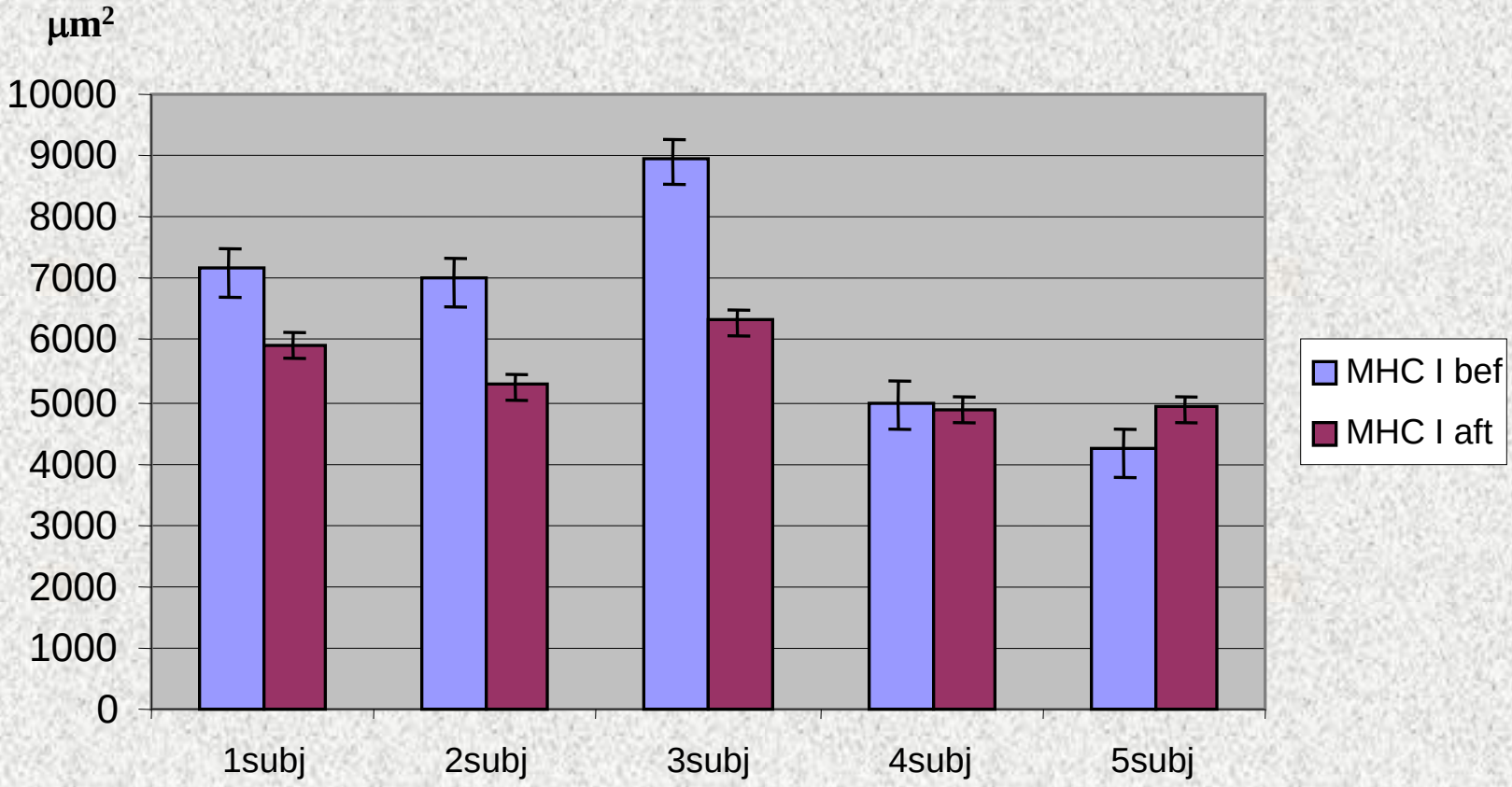
Methods :

- **Muscle samples were obtained from m. soleus of crewmembers before (L-60) and after spaceflight (R+1) by means of needle biopsy**
- **The immunofluorescent technique was applied for analysis of myosin heavy chain (MHC) isoforms. The monoclonal antibodies against slow (MHCs) и fast (MHCf) isoforms were used (Novocastra Laboratories)**
- **Image analysis was performed by means of Leica Quantimet system.**

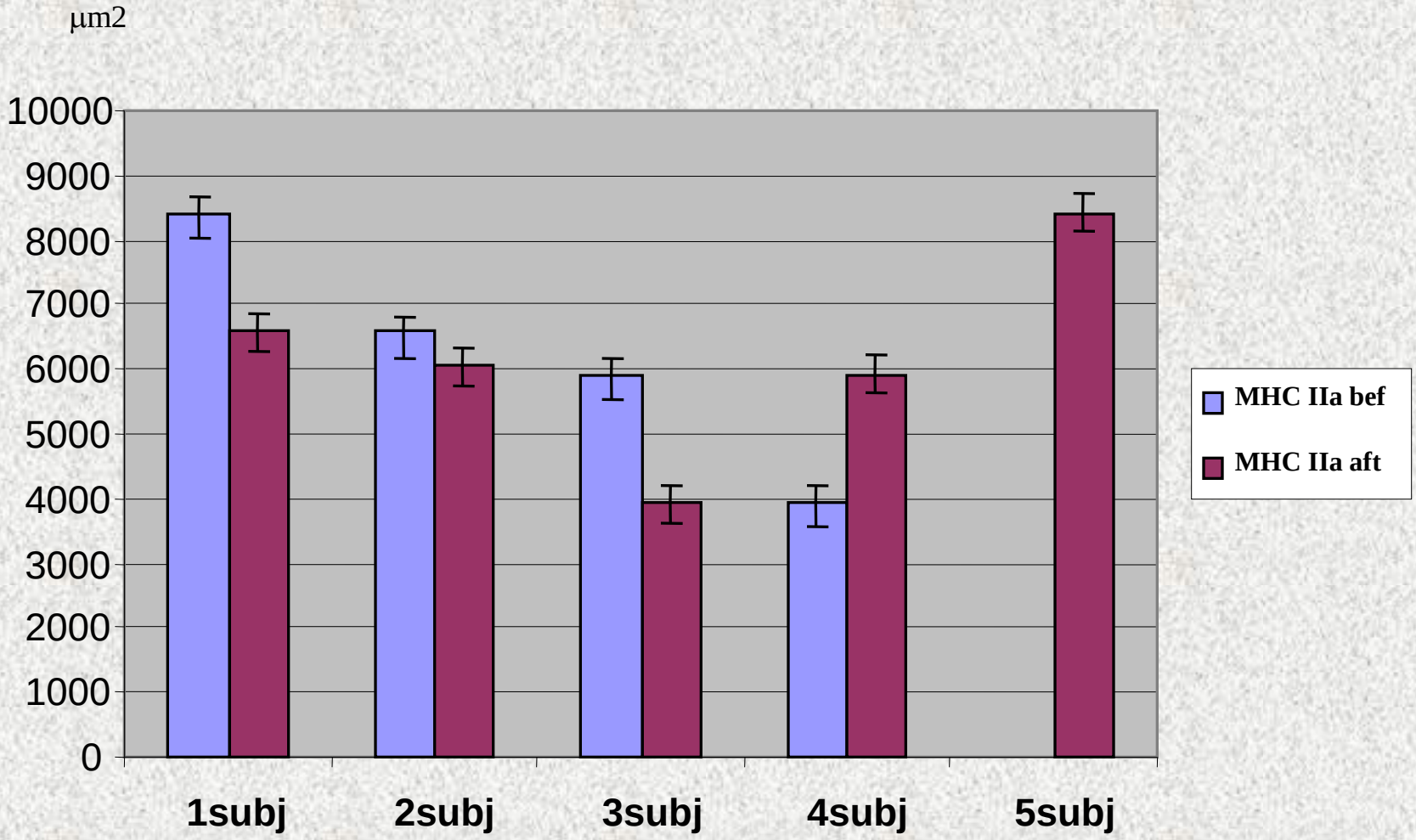
Results:

- **Those crewmembers who had performed countermeasure exercises in volume and intensity for ankle extensors low than recommended,were observed to reveal sufficient decline in soleus fiber sizes**
- **Those crewmembers who had performed adequate exercises for ankle extensors atrophic changes in soleus fibers were not found.**

MHC slow fibers cross-sectional area



MHC fast fibers cross-sectional area



Research and Development of Future countermeasures

Goals:

-- Optimization

- Increase of countermeasures efficacy:
- Enhancement of training facilities;
- Widening the range of active and passive countermeasure means;
- Increase of comfort of training devices;
- Development of environmental resistive training capabilities.

-- Automation

- Development of the autonomous system of training management;

-- Increase of reliability

-- Upgrading the technologies and approaches of inflight evaluation of countermeasures efficacy

“Penguin” Suit with the Load Measuring System (SIN PNK “Penguin”)

- The main advantage of the Penguin load measuring system is the existence of objective data about the loads to cosmonaut’s body, that is provided by the suit.

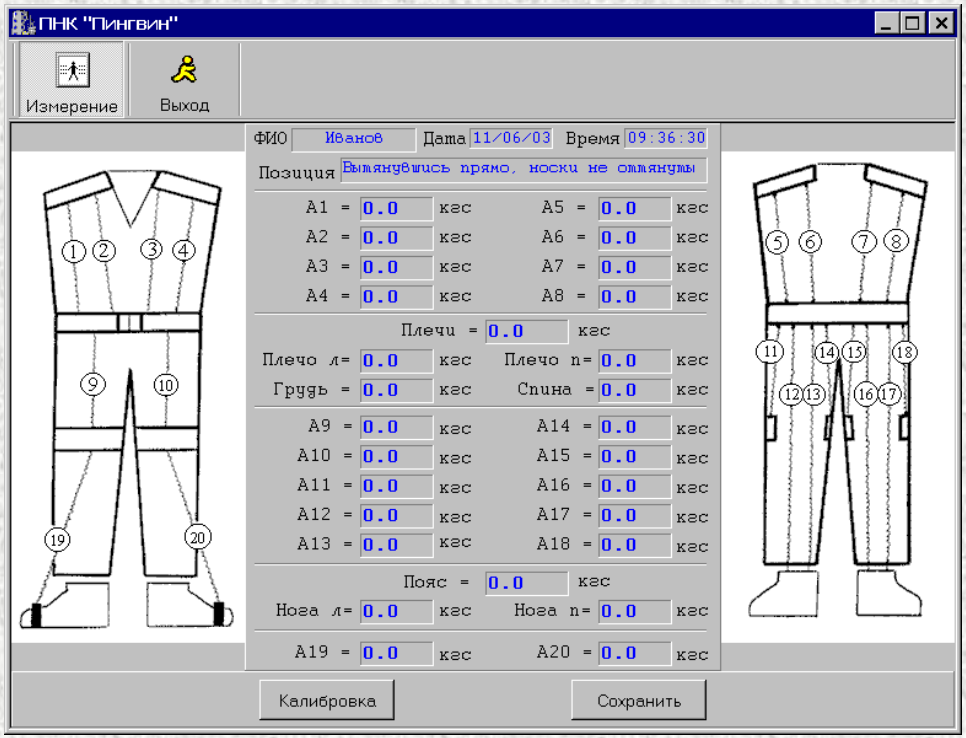
Redesigned components:

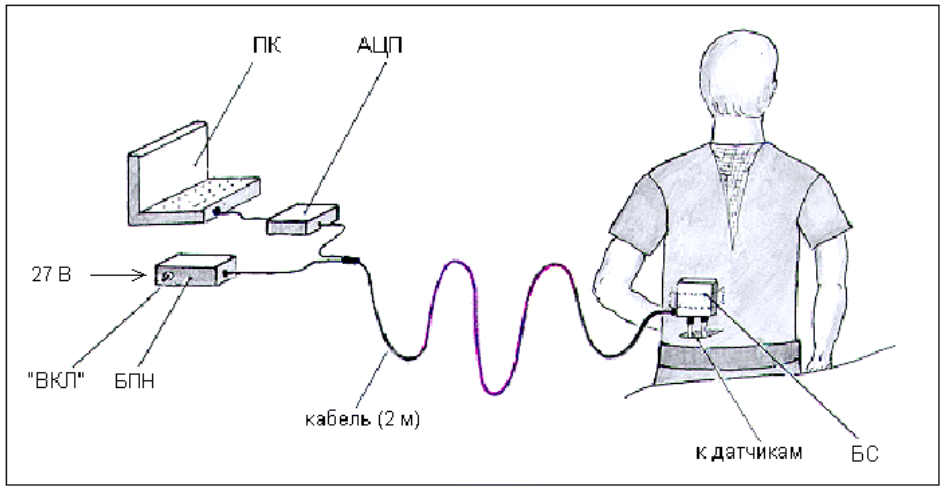
- Penguin-M will be outfitted with an automatic system for measuring tension of suit bungees. The system has an interface with onboard PC.

Status:

- The system passed the in-flight testing onboard the ISS.

“Penguin” Suit with the Load Measuring System

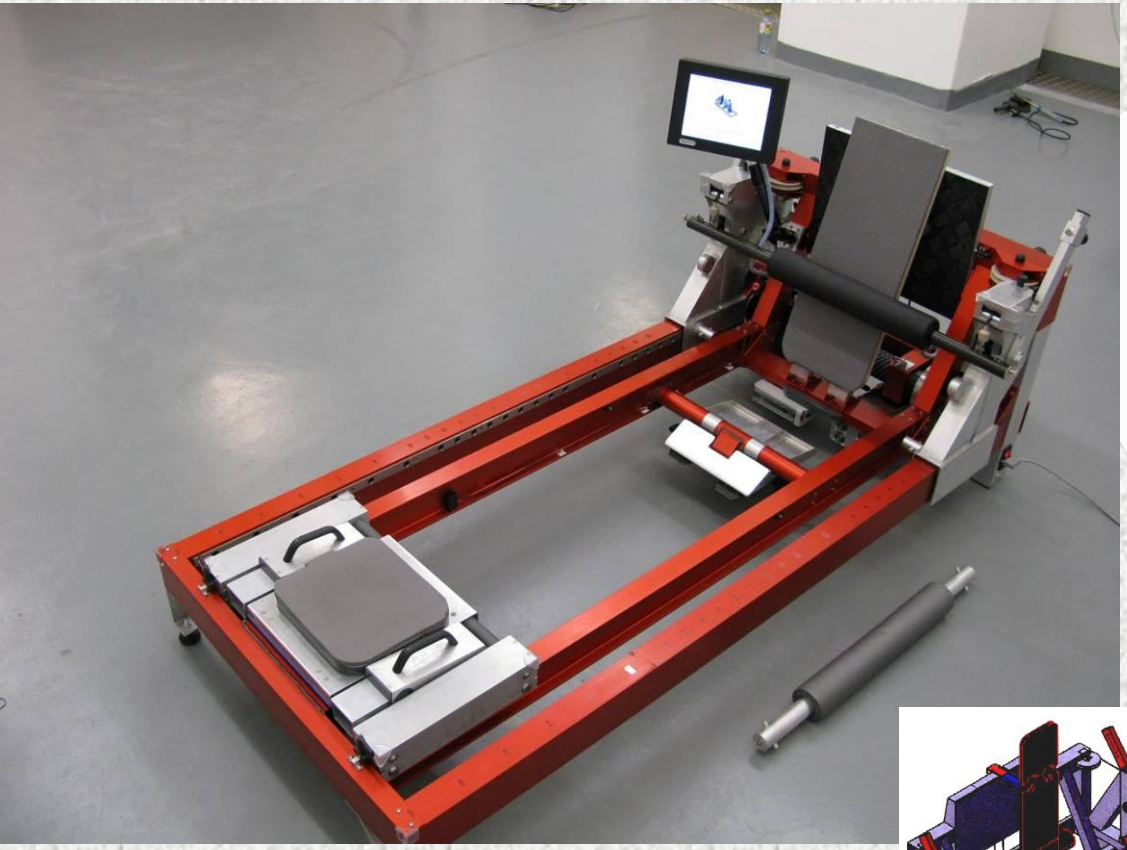


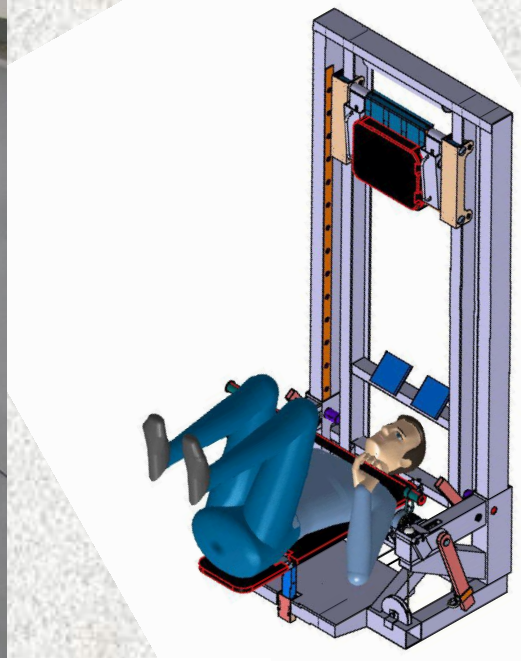


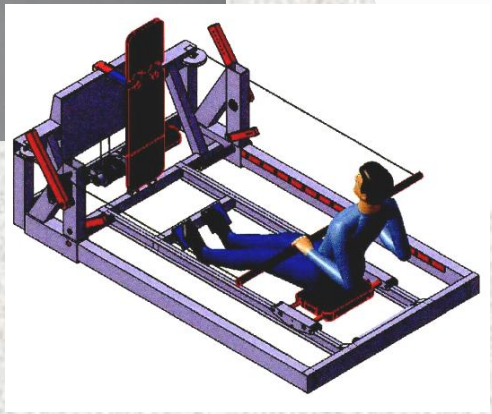
Computer-based LMS provides:

- Data sampling at a preset frequency (10 - 50 Hz);
- Display of tabulated actual loads to individual bungees and the total load value produced by the groups of bungees;
- Possibility to enter brief comments;
- Data retention.

New countermeasure device.
Multifunctional strength exercise device MDS





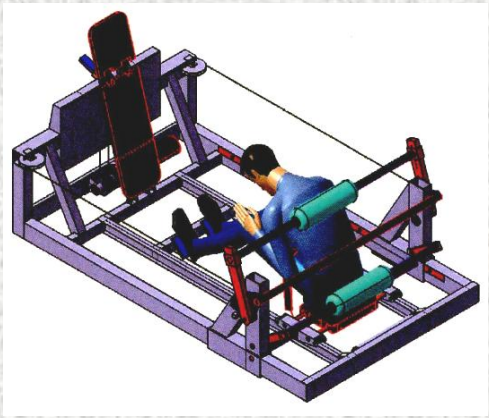


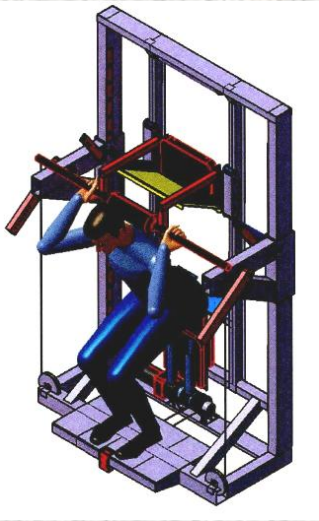
MDS EXERCISES

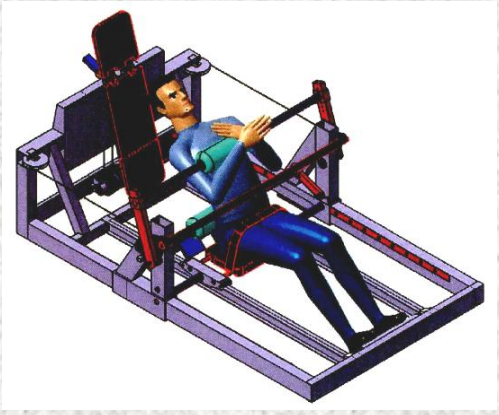
Eccentric, concentric and isometric exercises for arms, legs and the back..

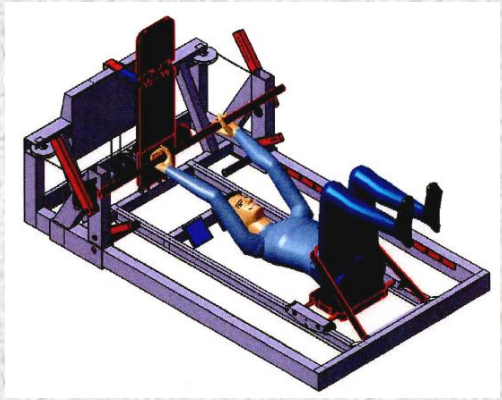
Types of exercise:

- Rowing
- Body flexion
- Body extension
- Forearm flexion/extension
- Leg press
- Bench press;
- Seated press;
- chin-up simulation.





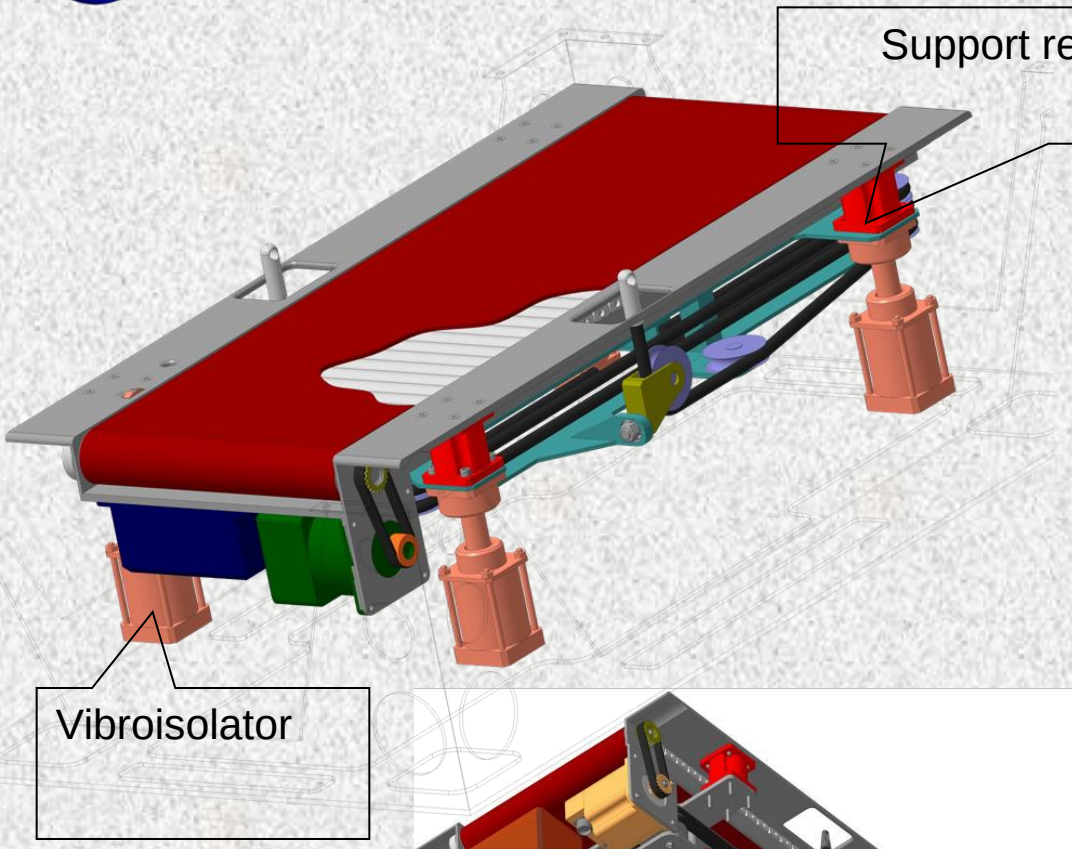


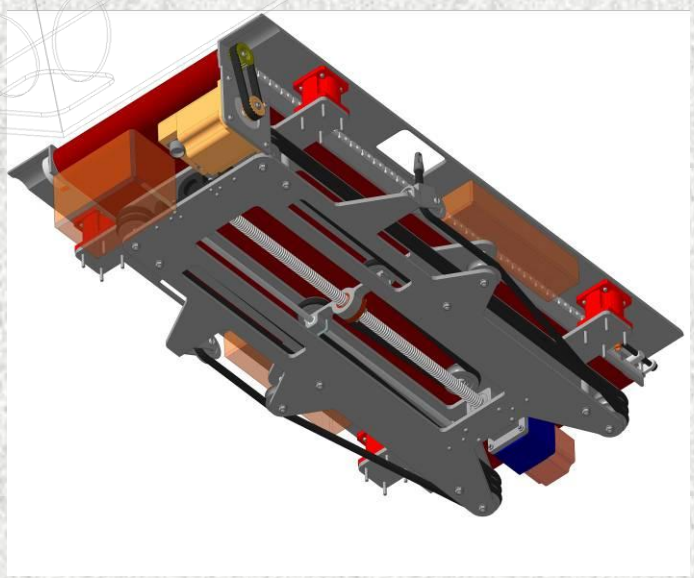


Status:

Now is under physiological testing in the 105-d experiment.

New countermeasure device. Treadmill BD-2

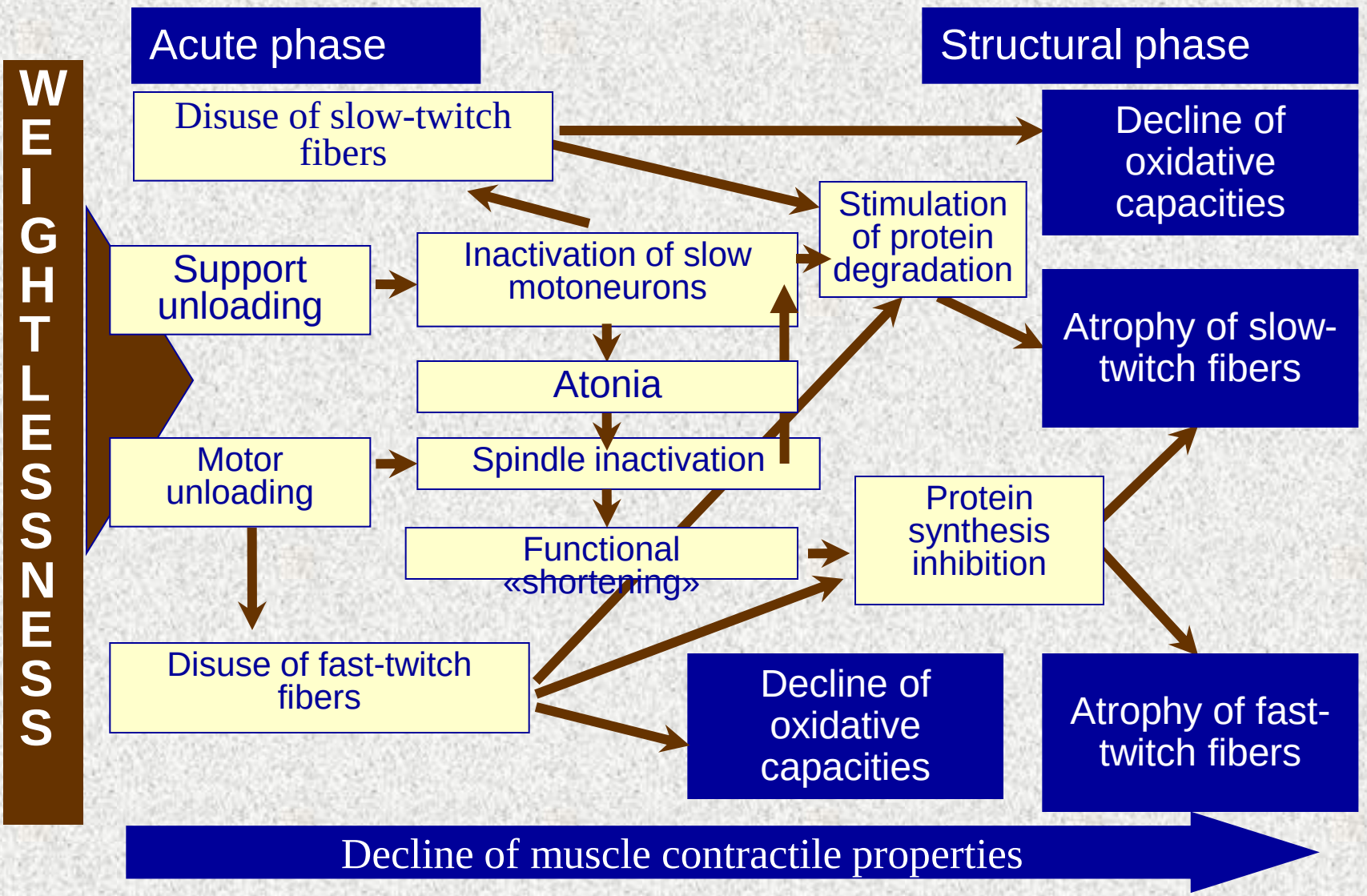




The treadmill allows human to walk and run :

- in motorized and non-motorized modes;
- With a speed from 2.4 to 20 km/hr;
- Having axial loading ranging from 40 to 70 kg;
- Using the vibroisolation system that provides the mechanic isolation from the station.

PHYSIOLOGICAL CONTROL OF MUSCLE PLASTICITY IN WEIGHTLESSNESS



NEW PASSIVE COUNTERMEASURES

Compensator of support unloading KOR-01-N

Status:

Autonomous testing at the designer's site.

Prototype was exposed to physiological testing in a 7-d dry immersion experiment.

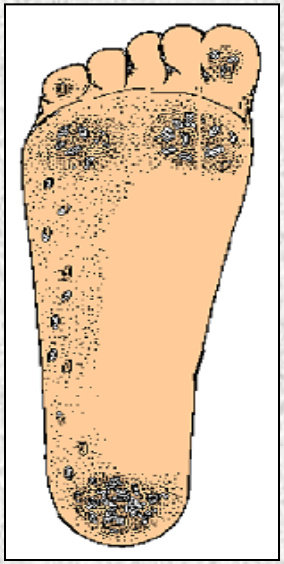
1. Two modes of mechanic stimulation:

a. walk-1 –75 steps/min;

b. walk-2 –120 steps/min.

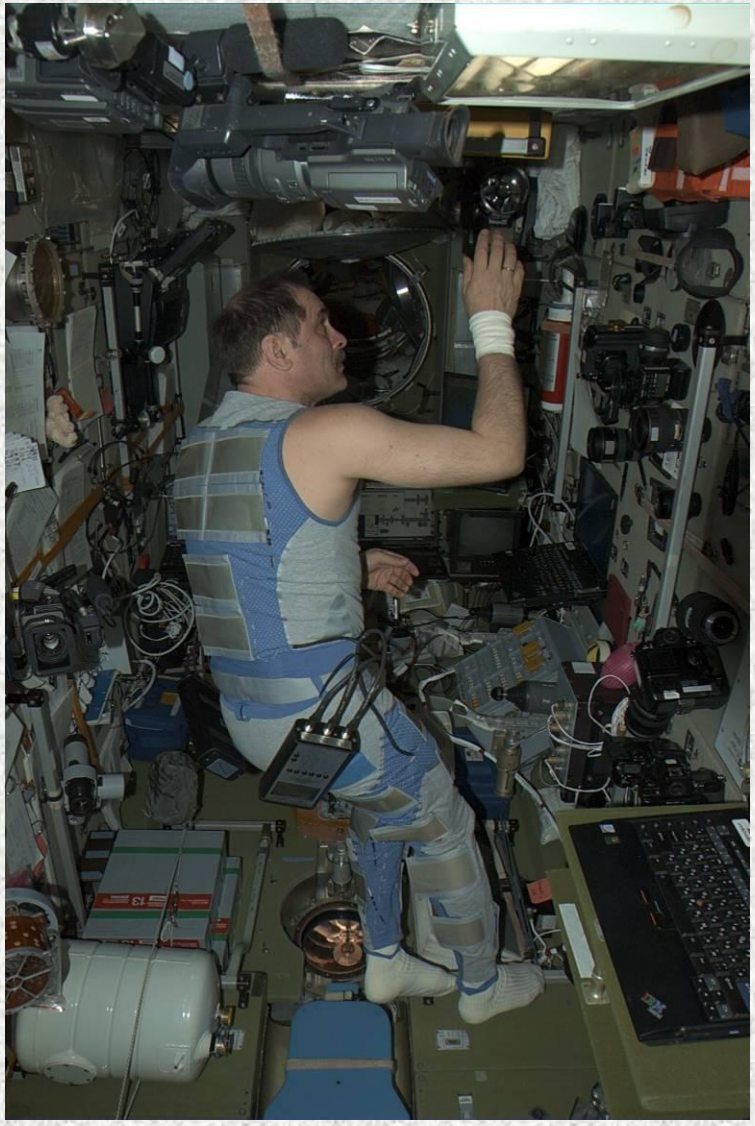
2. Pressure in air bladders – 0.15 to 0.5 кgf/cm^2

3. "Rigid" and "flexible" operating mode.



NEW PASSIVE COUNTERMEASURES

Suit “Stimul-01” NCh”



Electrical myostimulator is intended for low-frequency, low-amplitude stimulation of leg and back muscles.

Main components:
Electromyostimulator and suit.

Status:

Included into the ISS onboard countermeasure system.

ADVANCED COUNTERMEASURES UNDER DEVELOPMENT (candidates for application by Mars exploration crew)

1. Short-arm centrifuge;
2. Automated expert physical training control system;
3. Environmental resistive training capabilities